# MEMORANDUM

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**To:** Mary Kauffman (IDEQ) **Date:** April 6, 2006

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**From:** Mark Rettmann and Bill Wright (MWH) **Reference:** P4 Production Southeast Idaho Mine-Specific Selenium Program

**Subject:** Preface to *Grazing Reclaimed Minelands in SE Idaho*

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This memorandum functions as a preface to the report prepared by the veterinary toxicology panel, *Grazing Reclaimed Minelands in SE Idaho*. The panel was convened by P4 Production (a joint venture between Monsanto and Solutia) under a task in the site-specific investigation plans for each of their three historic mines.

## Panel

P4 Production's goal in assembling the veterinary toxicology panel was to find the most knowledgeable experts in Idaho and adjacent states. The panel consists of: Merl F. Raisbeck, DVM, MS, PhD, DABVT; Michael A. Smith, PhD; and, Patricia Talcott DVM, PhD, DABVT. Dr. Raisbeck, a veterinary toxicologist from the University of Wyoming with expertise of selenosis in cattle and other animals and experience in assisting the planning of Agrium's cattle study below South Maybe Mine, is the chairman of the panel. Dr. Smith is a range scientist from the University of Wyoming with expertise in range management and seleniferous vegetation. Dr. Talcott is a veterinary diagnostic toxicologist from the University of Idaho with expertise in trace element toxicity to animals, including selenosis research in SE Idaho. All three panel members have extensive experience with livestock in the Rocky Mountains.

P4 Production asked Kip Panter PhD, a USDA animal research scientist at Utah State University's Agricultural Research Service Poisonous Plant Research Laboratory. Dr. Panter has experience investigating the role of vegetative selenium in livestock poisonings in SE Idaho, but the USDA would not allow him to participate on the panel. P4 Production looks forward to Dr. Panter's ongoing involvement as reviewer for the USFS. In light of Dr. Panter's inability to participate, Dr. Raisbeck and Dr. Talcott asked P4 Production's permission to substitute a range scientist to bring valuable botanical expertise to the panel. P4 Production agreed and Dr. Smith was asked to be involved and accepted the position.

## Program Background

Phosphate mining has been an ongoing activity within southeast Idaho's Caribou County since 1919. Today three companies, including P4 Production, mine phosphate in area, and the ore obtained from these mines is locally processed into fertilizer and elemental phosphorus. Phosphate mining and processing form an important economic foundation for southeast Idaho.

In late 1996, several horses pastured downstream of a reclaimed phosphate mine were diagnosed with chronic selenosis. This event prompted concern by mine operators, the public, and local, state, and federal agencies about selenium impacts to the environment. The Idaho Mining Association (IMA) formed a Selenium Committee in spring 1997 to identify the source and extent of selenium and other trace element impacts associated with phosphate mining. The IMA voluntarily conducted multiple regional investigations through June 2000 and developed mitigation measures to address selenium and other target element releases and to minimize the potential threat to the environment. The IMA assisted the IDEQ with data collection as part of an agency-led 2001 area-wide study.

Since 2002, P4 Production has been conducting mine-specific site investigations (SIs) and engineering evaluations/cost analyses (EE/CAs) at their Enoch Valley, Henry, and Ballard mines. The veterinary toxicology task is being conducted in support of these SIs and EE/CAs.

**Veterinary Toxicology Task**

The objective of the veterinary toxicology panel was to review existing data and information on livestock exposure to seleniferous vegetation on waste rock dumps to determine the following:

- Safe levels of selenium in vegetation to allow different livestock species (cattle, sheep, and horses) to graze the dumps, including any mitigating measures (i.e., grazing duration, water supply) as necessary;

- A recommendation for what concentration of selenium in waste rock dump vegetation would be safe for all livestock species to graze without restriction; and,

- Identify further data needs to allow these determinations to be refined.

**Findings**

A brief summary of the panel’s findings are as follows:

- Reduce mine-related selenium exposures to livestock by eliminating or replacing seleniferous water sources, promoting use of adjacent, non-seleniferous range, delaying the onset of animal exposure to the dumps later in the summer when selenium concentrations should be lower, and eliminate and replace selenium-accumulating forbs (such as alfalfa);

- Don't allow horses to graze dumps;

- Monitor trace element levels in all livestock with access to dumps; and,

- Conduct additional livestock and forage studies to monitor effectiveness of above measures and to determine site-specific acceptable levels of selenium in forage.

**Conclusions**

*Grazing Reclaimed Minelands in SE Idaho* is not a decision document. It thus contains no solutions, but rather presents potential intensive range management solutions that will be developed as an alternative, or as input to a variety of alternatives, to be evaluated in each mine-specific EE/CA.

# Grazing Reclaimed Minelands in SE Idaho

***Prepared for MWH, 4/5/2006***

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## Executive Summary

Elevated forage Se concentrations *may* pose a hazard to grazing livestock on reclaimed areas at the Henry, Ballard and Enoch Valley mines. The authors were asked to produce a "zero risk" grazing plan; however insufficient data exists to do so or even to be sure that such a plan is possible. Production data from cattle grazing the Henry Mine indicates that there is (as yet) no problem, yet sheep have apparently been poisoned by Se-contaminated water from a pond on other phosphate mines in the area. The authors propose a series of conservative measures, based upon experience with livestock production in seleniferous areas of Wyoming, Nebraska and the Dakotas, which minimizes any risk to grazing livestock and which provides inputs (data) to better evaluate the extent of any risk and plan for future utilization of the sites. This plan includes: 1) eliminating sources of seleniferous water for livestock, 2) eliminating vegetation which tends to accumulate higher concentrations of Se, 3) adjusting pastures to incorporate more native (i.e., Se deficient) forage and 4) managing grazing to minimize Se exposure, all while getting full utilization of the resource.

## Background

Spontaneous selenosis, as a result of consuming naturally contaminated feedstuffs, has been recognized in the northern Great Plains states for approximately 80 years (Franke and Tully, 1934; Moxon, 1937; Moxon and Rhian, 1943). As a result, ranchers in many areas of Wyoming, Nebraska and the Dakotas have had to come up with management strategies that permit beneficial use of "toxic" pastures. More recently, it has been demonstrated that human activities, such as irrigation and strip mining, can mobilize Se from rocks and subsoil making it water soluble, that is biologically available, in the rooting zone of range vegetation (Naftz and Rice, 1988; Vance, 2000). Plants can be classified into "non-accumulator" and "accumulator" species (the latter classification is often subdivided into "facultative" and "obligate") on the basis of their ability to bioconcentrate Se from soil. The non-accumulator category is considerably larger and includes virtually all of the common forage grasses; the accumulators are mostly species regarded as weeds (e.g., *Astragalus bisulcatus*), but do include some useful forbs. These are apparently able to tolerate high Se soils by converting any Se absorbed to non-physiologic compounds that are readily eliminated.

Contrary to the older literature and urban legend, livestock are seldom poisoned by accumulator species as the latter produce volatile Se compounds that render them too unpalatable for livestock to consume. Significant consumption of accumulator species by cattle or sheep requires extremes of starvation and mismanagement. Non-accumulators such as grasses, clovers and alfalfa accumulate Se primarily as L-selenomethionine (substituted for methionine) in protein and, as a result, there is little if any odor or taste associated with non-accumulator species. Thus, even though non-accumulators accumulate much less Se than the accumulator species, grazing animals willingly consume the former in much larger quantities than the latter, ultimately resulting in elevated Se exposure. Parenthetically, it is worth noting that most "mineral" supplements consist of inorganic Se salts, notably selenate and selenite because they are much cheaper than "natural" sources of the mineral. For the same reason, most of the literature dealing with selenium poisoning was derived from experiments with inorganic forms of selenium and/or case reports of iatrogenic poisoning.

The relative toxicity of inorganic Se salts, especially selenate and selenite, vs. selenomethionine is controversial. Some experimental studies, especially acute or subacute toxicity experiments, suggest that inorganic Se is more toxic on a per mole Se basis. Others, especially chronic studies, seem to indicate that there is no difference in potency or that selenomethionine is slightly more potent. This divergence of results may be because Se is prone to a multiplicity of interactions with other dietary factors and because of variation in the experimental endpoints chosen. However, virtually all experiments to date, including several in our laboratories (Raisbeck *et al.*, 1998; Pehrson *et al.*, 1999), agree that Se from Semet accumulates to significantly higher concentrations in most tissues than equivalent exposure from inorganic Se. In fact the USDA has funded studies that take advantage of this property to increase the Se concentration of a number of American foodstuffs including beef and garlic, to "supranutritional" concentrations (e.g., McAdam *et al.*, 1987; Schrauzer, 2001; Rayman, 2004).

Dietary uptake (and thus toxicity) of Se also varies with animal species, age, chemical form of Se and the presence or absence of dietary antagonists. Absorption of selenium in ruminants is less than in nonruminants (Wright and Bell, 1966) and the authors have investigated numerous cases in which horses were poisoned while cattle grazing the same pasture were unaffected (Raisbeck *et al.*, unpublished). A wide variety of inorganic dietary substances, including Zn, Te, As, Ag, Cu, and S have been reported to antagonize the bioavailability of Se. Although most studies of these interactions have focused upon nutritional or sub-nutritional Se levels, there is no obvious reason to doubt that similar interactions occur at toxic concentrations. In fish and avians, Hg forms a biologically inactive complex with Se resulting in extremely high tissue concentrations of both elements. Although these concentrations are many times higher than commonly associated with poisoning there is no biological effect in the animal. This phenomenon has not been thoroughly examined in mammals, but appears to occur (Juresa *et al.*, 2005). A number of naturally occurring organic substances such as the cyanogenic glycosides, dietary protein and methionine, have been shown to promote the excretion of and/or minimize the effects of Se. Interestingly, even Se deficiency increases the sensitivity to toxic amounts of Se. The upshot of all this is that *the potential hazard or safety of a given amount and form of Se has to be evaluated in the context of the animal's environment* and not just extrapolated from other species, situations, etc.

Clinical signs of selenosis (selenium poisoning) vary with the rate of intake, but can be generally divided into acute and chronic. Acute poisoning usually results from the ingestion of inorganic Se salts such as selenate or selenite and may present as sudden death with few premonitory signs or a relatively short course of clinical signs typical of damage to the gut, liver, kidney and cardiovascular system. Chronic selenosis is most uniquely characterized by damage to epithelial tissues, notably hoof and hair/skin. Other damage attributed to, but poorly documented in, chronic selenosis includes reproductive failure, arthritis, anemia and "dishrag" heart. (See Raisbeck (2000) for a more detailed treatment of the clinical aspects of selenosis.)

"Toxic levels", dietary concentrations that *might* cause selenosis, are commonly derived from experimental studies or anecdotal (case) studies. Both have strengths and weaknesses; the former tend to be much more reproducible (reliable) as extraneous variables are controlled while the latter theoretically better represent the "real" world, but at the expense of uncontrolled confounding factors. For example, the Se literature is still contaminated with the attribution of "blind staggers", a condition that is most likely sulfur-induced polioencephalomalacia, to Se (Raisbeck *et al.*, 1993; O'Toole *et al.*, 1996; O'Toole and Raisbeck, 1998).

*Acute* oral poisoning in ruminant species requires doses considerably in excess of 1 (usually 2-10) mg Se per kg body weight (Carvaggi *et al.*, 1970; Fessler *et al.*, 2003; Grace, 1994; Miller and Williams, 1940; Puls, 1994; Shortridge, 1971; Morrow, 1968). At least in cattle, such poisoning almost never results from naturally contaminated forages, as plants that contain sufficient Se to be acutely toxic are *extremely* unpalatable. There are a few poorly documented anecdotal reports suggesting that sheep, if starved long enough, will eat Se-accumulators, but numerous attempts to reproduce such with seleniferous weeds were unsuccessful (J.O. Tucker, 1960 and *personal communication*; E.L Belden, *personal communication*). Apparently, acute poisoning by inorganic Se salts in water is possible under field conditions if concentrations are high enough (Talcott, unpublished). This is possible because 1) inorganic salts do not significantly reduce the palatability of water and 2) under some conditions (e.g., hot weather, long trail drives) animals will drink quantities of water several times greater than their total daily dry feed intake.

In the context of this report, the most relevant experimental data comes from "natural" feeding trials in which ruminants received Se as part of their regular diet rather than by injection or gavage. Unfortunately, well-controlled feeding studies are relatively rare. "Organic" Se (i.e., selenomethionine from high Se forages or selenized yeast) had no discernable effect on cattle when fed at 11.9 ppm Se (roughly equivalent to 0.36 mg/kg body weight) for 14 weeks (Hintze, 2002). Another group of steers were fed 0.065 mg/kg/day for 120 days with no effect on growth or carcass quality (Lawler *et al.*, 2004). Steers fed 0.15, 0.28 or 0.8 mg L-selenomethionine per kg body weight (corresponding to roughly 6, 12 and 30 ppm) for 120 days exhibited no clinical signs, *post-mortem* lesions, or clinico-pathological changes indicative of toxicity, although there was some evidence of possible subclinical disease (e.g., immunosuppression) in the latter group (Raisbeck *et al.*, 1998a; Raisbeck and O'Toole, 1998; Raisbeck *et al.*, 1998b). Conversely, Ellis *et al.*, (1997) fed adult Holstein cows sodium selenite at 87-118 µ/kg BW for 128 days with no adverse effects on the immune system. Jenkins and Hidiroglou (1986) reported "reduced performance" in baby calves at 10, but not 5 ppm dietary Se as selenite. Since the selenite was mixed with milk replacer, it is likely that the calves received the entire daily dose as one or two boluses.

Contrary to assertion (Bollar *et al.*, 2001) that more than 0.3 ppm is toxic in sheep, Echevarria *et al.*, (1988) noted no toxic effects in sheep fed 9 ppm Se as added selenite (equivalent to 180 µ/kg BW) for 30 days. Fessler *et al.* (2003) reported that 24 sheep maintained on a pasture with "<13.0 ppm Se" for 4 weeks showed no evidence of toxicity. *One* of another 24 sheep maintained on "<49 ppm" forage and *340-415 ppb water* (estimated exposure 0.26 mg/kg BW) died. No mention was made of how water consumption was estimated. Body weight gain, estrous cycle and lambing of yearling ewes were unaffected by feeding high concentrations of Se as either sodium selenite (24 ppm Se) or *Astragalus* (29 ppm Se) for 88 days (Panter *et al.*, 1995). Cristaldi *et al.* (2005) fed up to 10 ppm Se as selenite to sheep for one year with "no apparent pathological evidence of selenosis". Davis (2004) fed ewes diets containing up to 20 ppm Se (as selenite) for 72 weeks with no apparent effects on reproduction, etc. Davis also fed up to 40 ppm Se from either selenite or selenized yeast for 60 weeks with no toxic effects noted (McDowell *et al.*, 2005). Goats receiving repeated daily doses (i.e., by gavage or capsule) of 0.25, 0.5 or 1.0 mg/kg selenite for 225 days showed no clinical signs of toxicosis or histological changes (Ahmed *et al.*, 1990). Death occurred when the dose was increased to 5 mg/kg.

From the foregoing it would appear that the chronic "toxic level" of Se for ruminants, if derived from a normal diet, is between 5 and 25 ppm. This is considerably higher than the 2 ppm cited in the NRC in 1980 but probably is more appropriate to cattle and sheep grazing western rangelands than a number extrapolated from rodent studies and dosing studies. In fact the latest version of *Mineral Tolerance of Animals* makes note of the fact and says "Maximum tolerable levels of selenium for given species in the future should be specifically defined with different forms of selenium, duration of exposure time, and nature of diet." (NRC, 2005).

**Characteristics of the forage resource and animals**

The presence of potentially toxic Se concentrations in the Soda Springs area first came to light when several horses developed signs of alkali disease while on a pasture with drinking water from and sub-irrigated by Maybe Creek. The water apparently contained >>0.5 ppm Se as a result of flowing through a spoil pile from historic phosphate mining. Vegetation samples collected by a UW investigator contained over 200 ppm Se (Vance, 2000). Sometime later a number of sheep died at a pond beneath a spoil pile. The first author reviewed the pathology and toxicology data from the sheep incident for the University of Idaho and concluded that the principle source of Se "was most probably inorganic Se in water". Another sheep episode may have involved water or a combination of water and seleniferous vegetation. *None of these mortalities occurred on one of the 3 mines covered by this report.* However, the mines covered in this report are located in the same area and utilize generally similar reclamation procedures, thus one has to consider the possibility that similar problems may occur on the Henry, Ballard and Enoch Valley mines.

In September 2005, the authors toured the Ballard, Henry and Enoch Valley mines. The mines have been reclaimed for up to 25 years, with final reclamation at Enoch Valley still underway. The grazing area of each consists of varying amounts of reclaimed mine spoil vegetated with a species mix dominated by introduced wheatgrasses (*Agropyron sp*.), alfalfa (*Medicago sativa*) and native range species - sagebrush (*Artemisia tridentata*), wheatgrasses, (*Agropyron sp*.) bluegrasses (*Poa pratensis, Poa canbii*) and forbs such as *Lupinus sp*. *Crepis sp.*, and *Achillea sp*. In at least one case (Ballard) the only source of water is contaminated with Se. The Ballard mine was reclaimed first, in the early 1970's, followed by the Henry mine in the early 1990's. Presumably, reclamation practices varied during this period as vegetation Se concentrations in various studies on the Ballard Mine are noticeably higher than from either of the other two. Additionally, a portion of seleniferous waste on the Enoch Valley mine has been capped with about 10' of limestone, a practice which seems to limit availability to forages (Bryson, 2005).

It is dangerous to draw too many conclusions from existing vegetation data as only one study, an incomplete MS thesis by U of I student Jeff Knight, actually sampled in a fashion applicable to animal health. This dataset consists of samples of grass and alfalfa "collected at random locations in both reclaimed and native areas of the Henry and Enoch Valley mines" according to a scheme typical of grazing nutrition studies. Selenium concentrations from reclaimed sites ranged from a high of 75 ppm (one alfalfa sample) to a low of 0.81 ppm (grass). The highest grass Se concentration was 8.6 ppm, most were less than 5.0 ppm. Native grass samples were all below concentrations commonly regarded as adequate for animal health. Other results, culled from various reports on the Henry and Enoch Valley mines, do not contradict the Knight data but are insufficient in themselves to draw many conclusions. Soil samples collected at the same time as the Knight samples appear to be measured as total Se, which, in the authors' experience, is irrelevant from the standpoint of predicting Se availability to grazing animals.

The current agricultural use of these reclaimed areas is the summer grazing of cattle. Reclaimed areas on the Henry mine have been grazed every summer since it was reclaimed. Discussions with the livestock owner, Mr. Bruce Dredge, indicated he has not experienced any reproductive or health problems in his herd and that his records suggest that the cattle are producing (# calves weaned, weaning weights, % culls) at levels typical of a well-managed beef herd in the Rocky Mountain west. Visual examination of cattle on the Henry site in September did not reveal any of the clinical signs typical of selenosis. Although the Ballard and Enoch valley mines have not been systematically grazed, there have been occasional livestock incursions from adjacent properties with no reported adverse effects. A study of elk grazing on and off the sites indicated that the herd was healthy and increasing (Kuck, 2003).

In the U of I study, steers, grazing the same ground as sampled for forage Se above, remained clinically healthy both during the approximately 90 day grazing period and during the 4 month depletion period following. Blood Se concentrations varied considerably, both while on pasture and during the depletion period. Assuming the diet consisted of L-selenomethionine and extrapolating from controlled feeding studies (Raisbeck *et al.*, 1998), the blood concentrations (1 - 4.5 ppm) while on the site suggest exposure to forage Se concentrations between <5 ppm and 26 ppm. This, in turn, suggests that at least some of the cattle were selectively grazing the high-Se alfalfa, as most grass samples were less than 5 ppm.

**Recommendations for grazing and forage management**

There is no way to devise a "zero risk" grazing program from the information that the authors have been provided. There are, in fact, no zero risk strategies associated with any range operation. There is, however, a substantial experience base, bolstered by research, which can be tapped to permit grazing to take place with *minimal* risks. The authors offer the following *conservative* recommendations to minimize risks to grazing livestock on the Henry and Enoch Valley mines.

1) Water from springs and seeps draining the seleniferous spoils should be fenced to prevent potential exposure to stock. Water developments in the grazing areas should be placed adjacent to or off the seleniferous area and supplied with low Se water. Rationale: A mature cow in summer can consume more than 20 gallons (75 L) of water daily, but seldom eats more than 10-12 kg during the same period. Thus, a given Se concentration in water will provide roughly 7X the exposure of the same concentration in diet even before bioavailability is taken into consideration.

2) Grazing should be timed to coincide with the lowest forage Se concentrations. Rationale: Although seasonal testing of forages (see below) would be advisable to verify this assumption under local conditions, experience in South Dakota suggests that, as plants become mature, the Se concentration drops. This is probably because most of the Se is associated with the protein fraction of the forage and protein content declines and fiber content increases with advancing maturity.

3) Where feasible, the producer should consider using a shorter grazing period but grazing more animals to get the same number of animal days of grazing. Tissue monitoring of both animals and forage for Se should be conducted and general health and production parameters determined. Rationale: Shorter grazing periods minimize the opportunity to

graze regrowth, especially alfalfa, which will be higher in Se. A shorter, more intensive, grazing program appears to minimize body Se burden and thus adverse effects on some ranches in seleniferous areas of Wyoming, Nebraska, etc. Current (i.e., since reclamation) grazing periods on the Henry Mine have apparently not been sufficient to impact animals, but the question remains how much, if any, risk would be associated with longer grazing seasons. Data from monitoring will be useful in refining and extending this observation to future grazing practices and to warn of any incipient problems.

4) Inclusion of non-seleniferous native areas in pastures and encouraging their use by strategic placement of salt blocks, water, etc. is advisable. Rationale: Native forages in the area are *very* low in Se, both by analysis of the forages themselves and especially by virtue of the fact that producers in this area commonly supplement with Se to prevent Se deficiency in livestock. Including native areas in moderately seleniferous pastures such as found on these mines will serve to dilute the consumption of high Se forages to reasonable intakes.

5) Alfalfa and Se-accumulator forbs should be reduced by selective broadleaf herbicide treatment. Rationale: This has two beneficial effects: First, deletion of alfalfa and the non-indicator forbs from the revegetated areas would make them less available to grazing animals. Secondly, these species (especially the indicators) accumulate many-fold more Se than do grasses grown on the same soils and *may* be involved in mobilizing Se from subsoil.

6) All animals grazing these sites should be monitored for trace elements, especially Cu, and their diet adjusted accordingly with trace mineral salt or other commonly accepted practices. Rationale: Certain trace elements are known to interact with supranutritional Se and some (e.g., Cu) are known to be deficient in the Soda Springs region. Maintaining tissue concentrations of the major trace elements within the optimum range for health will minimize the likelihood of any adverse interactions.

7) Pastures should not be used for horses. Rationale: Although the literature is conflicting as to the relative chronic toxicity of Se in horses vs. ruminants, our experience indicates that horses are much more sensitive to alkali disease than ruminants.

The Ballard Mine represents a separate issue. The data we reviewed (e.g., the IMA Final Regional Investigation of 1998 and the dataset from the "mass-wasting" study of 2004) seem to indicate *consistently* high vegetative Se concentrations. These data are possibly skewed by the special purposes of the studies from which they were drawn but, in the absence of any other data (especially grazing studies) the authors recommend approaching this site slightly differently. The forage on this site should be surveyed for Se by collecting samples in a manner appropriate to grazing ruminants, or by placing sentinel animals on the site. The latter procedure is preferred as it more accurately determines the real risk. If sentinel animal monitoring is chosen all of the above recommendations apply, with increased emphasis on frequent, periodic monitoring and some provision for indemnity if adverse health effects do occur.

**Further testing**

After spending many hours reviewing data contained in dozens of pounds of documents, the authors haven't found the information needed to reliably predict the outcome of long-term grazing on reclaimed areas on the Henry, Ballard and Enoch Valley mines. Specifically, there is insufficient data describing the amount of biologically available Se on these three mines and its effect(s) under *local* conditions on grazing ruminants. Based upon up to 25 years of grazing the Henry Mine, there is apparently insufficient Se to cause problems, but 1) a baseline with which to compare future data would be useful in monitoring changes as the seleniferous materials weather; 2) such data will help extrapolate from these sites to similar sites on other mines in the area; and 3) predict, based upon controlled research in other states, long term outcomes of such grazing. Specifically, the authors recommend:

1) Periodic blood Se tests before, during and after grazing the reclaimed areas of the Henry, Ballard and Enoch Valley mines.

    a. It may also be useful to include general health exams and clinicopathological blood tests as potential early indicators of subclinical disease; however, it should be borne in mind that these test are *not* specific for Se. Other, more specific, tests might be adapted from research methods, but would have to be validated for use under field conditions.

    b. Trace element evaluation of serum while on pasture or liver after the grazing season (see #6 above). At a minimum, this panel should include Cu, Mo and Zn, however more extensive panels are cheaply available.

2) Production data, i.e., conception rates, weaning rates, weaning weights and % culls of animals (and their offspring) which graze these sites.

3) Forage Se concentrations at various points during the grazing season. Samples should be collected such that they represent Se concentrations in vegetation that animals actually eat. There are two widely accepted sampling strategies for such sampling: 1) modified bite count, in which animals are observed and samples of the species and locations they prefer collected for analysis in proportion to the amount consumed, or 2) systematic selection of plants likely to be consumed along transects based around areas where animals congregate and travel, such as water sources and salt blocks. Roots and ground level portions of plants are unlikely to be consumed and, as such, are irrelevant to the question at hand.

    a) A second consideration of forage testing is the possibility of identifying "hot spots", if any exist. The existing data isn't sufficient to tell whether or not such exist, but in many cases the bulk of really seleniferous vegetation will be localized to relatively small areas of a pasture. Excluding hot spots with fencing has been used by producers in seleniferous areas to permit grazing pastures that are otherwise regarded as unusable.

b) If possible, #3 should differentiate between selenomethionine and other forms of Se.

**Summary**

Elevated forage Se concentrations *may* pose a hazard to grazing livestock on reclaimed areas at the Henry, Ballard and Enoch Valley mines. While there are no “magic bullets”, the authors believe, based upon historical grazing records and limited forage data, that it should be possible to profitably and safely utilize the Henry and Enoch Valley sites for typical summer grazing (3-4 months) of cattle and sheep if the appropriate precautions are taken. The authors cannot make the same statement about the Ballard Mine without better data from either forage sampling or sentinel animals or both. If undertaken, this program will require a long-term, at least 5-10 years, commitment from (and cooperation between) the mines, regulators and livestock owners to make it work. However, given the expense and environmental disruption of the alternatives, the authors feel it is worth a try.

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